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14. ABSTRACT

The STIR proposal aims at understanding Internet users' online activities from the influence of a pointing device, such as a mouse, touch pad, and stylus, to an on-screen target. This will allow us to use this new understanding to identify potential cyber threats such as bot actions. There are four tasks proposed in the project: (1) PI will apply Fitts' law formula to pointing actions in a natural web browsing environment in an attempt to assess Fitts' law's applicability to typical GUIs outside of an experimental setting. (2) PI will identify whether or not fast movements have a different error model from slow movements and study the impact induced by the open loop nature of fast

15. SUBJECT TERMS

Movement of a pointing device, Web browsing, Fitts' Law

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Report Title

Final Report: The Investigation of Pointing Behaviors in Web Browsing

ABSTRACT

The STIR proposal aims at understanding Internet users' online activities from the influence of a pointing device, such as a mouse, touch pad, and stylus, to an on-screen target. This will allow us to use this new understanding to identify potential cyber threats such as bot actions. There are four tasks proposed in the project: (1) PI will apply Fitts' law formula to pointing actions in a natural web browsing environment in an attempt to assess Fitts' law's applicability to typical GUIs outside of an experimental setting. (2) PI will identify whether or not fast movements have a different error model from slow movements and study the impact induced by the open-loop nature of fast movements. (3) PI will comparison of Fitts' law results for natural browsing using two different pointing devices: physical mouse and laptop touchpad in order to determine whether the choice of pointing device has an effect on the linear relationship described by Fitts' law. (4) PI will analyze the standard deviation of Fitts' law calculations of mean pointing time, to better understand the variance present in the Fitts model.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received   Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received   Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

A Large-Scale Study of Fitts' Law in Web Browsing.

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received		Paper

06/16/2016 1.00 . PmDroid: Permission Supervision for Android Advertising,
The 34th IEEE Symposium on Reliable Distributed Systems (SRDS 2015). 01-OCT-15, Montreal, Canada. : ,

06/17/2016 2.00 . Privacy Risk Assessment on Online Photos,
The 18th International Symposium on Research in Attacks, Intrusions and Defenses. 03-NOV-15, Kyoto, Japan. : ,

06/17/2016 3.00 . SERF: Optimization of Socially Sourced Images using Psychovisual Enhancements,
7th ACM Multimedia Systems Conference (MMSys 2016). 12-MAY-16, Klagenfurt, Austria. : ,

09/26/2016 5.00 . A Study of Personal Information in Human-chosen Passwords and Its Security Implications,
2016 IEEE International Conference on Computer Communications (INFOCOM'16). 11-APR-16, San Francisco, CA, USA. : ,

TOTAL: **4**

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received	Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received	Paper

TOTAL:

Number of Manuscripts:

Books

Received   Book

TOTAL:

Received   Book Chapter

TOTAL:

Patents Submitted

- Methods and Systems for Increased Debugging Transparency.

Patents Awarded

Awards

Best Paper Award in USENIX LISA 2015, Washington, D.C., November 2015.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Haitao Xu	0.50	
Aaron Koehl	0.50	
FTE Equivalent:	**1.00**	
Total Number:	**2**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Haining Wang	0.30	
FTE Equivalent:	**0.30**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics
This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Haitao Xu
Aaron Koehl
Total Number: 2

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

This project examined the Fitts' model in the context of natural web browsing. Mouse movement data from more than 1,000 real-world Internet users was collected via Javascript embedded on a web forum, and the analysis showed a linear relationship between the ID and MT of the task with over 98% correlation, suggesting strong evidence that Fitts' law extends well to web browsing behavior. In addition, we evaluated the deviation in raw movement time from Fitts' predicted MT, especially the error model proposed by previous works. From the raw data, there exists a large deviation from Fitts' predicted values, with a 46.40% mean absolute deviation. We further divided all movements into three categories by the Fitts' predicted MT: slow, medium, and fast movements. And fast movements were shown to have an error model different from the other two categories, which indicates their open-looped nature.

Moreover, this project examined the effect of differing pointing devices on the Fitts model. Pointing data was collected from 10 people variously using physical mice and laptop touch pads. The analysis showed that both devices had a strong linear relationship between ID and MT (over 98% correlation in both cases), and that the results were nearly identical at low ID values, yet diverged slightly at high ID values. Finally, this project discussed other Fitts' Law considerations, namely the standard deviation in Fitts' Law calculations. The forum data set was analyzed and the standard deviation of MT plotted against ID. The result showed that Fitts' Law also describes a linear relationship between ID and standard deviation, implying that variance in time to point increases as ID increases.

Overall, this project attempts to answer the question: how well does Fitts' law truly model real human pointing tasks in web browsing? This is accomplished through a data set collected from 1,047 users' natural mouse traces on a real-world website. The major accomplishments of this project are summarized as follows:

1. An application of the Fitts' law formula to pointing actions in a natural web browsing environment, involving a large-scale data collection from 1,047 real-world users on an Internet forum, to assess Fitts' law's applicability to typical GUIs outside of an experimental setting.

2. An observation that in web browsing, fast movements have a different error model from slow movements, which deviates from previous laboratory studies. We speculate that this is partially due to the open-loop nature of fast movements.

3. A comparison of Fitts' law results for natural browsing using two different pointing devices $-$ physical mouse and laptop touchpad $-$ to determine whether the choice of pointing device has an effect on the linear relationship described by Fitts' law.

4. An analysis of the standard deviation of Fitts' law calculations of mean pointing time, to better understand the variance.

Technology Transfer

From our study, we have learned that the way one can apply Fitts' law to web browsing is different from what previous works describe for restricted laboratory settings. Therefore, we have summarized a suggested guideline on how to apply Fitts' law model in web browsing as follows and shared it with research and industry communities:

1. Data Collection: Besides x-y coordinates and time-stamps, target types must be recorded as well, as it is needed to measure the target width.

2. Clustering and Averaging: Sort all records with increasing IDs, choose a proper cluster size S (our results show that S > 40 yields optimal results), then average every S raw data.

3. Linear Regression: Plot the averaged ID and MT pairs, fit them in a straight line, and calculate parameters a and b. Note that they are user- and environment-specific.

ARO Final Project Report
PI: Haining Wang

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